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U. S. DEPARTMENT OF AGRICULTURE

Opinions and Practices of Manufacturers Regarding

FIBERS USED in INSULATED WIRE and CABLE

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service Washington, D. C.

Marketing Research Report No. 85

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PREFACE

This report deals with one of a series of studies of consumption of farm products, conducted by the Market Development Branch of the Marketing Research Division, Agricultural Marketing Service. The study was made under the direction of Trienah Meyers.

The research reported in this release was conducted under authority of the Agricultural Marketing Act of 1946 (RMA, Title II). The Agricultural Marketing Service received cooperation and advice from other agencies in the Department, particularly Agricultural Research Service, other government agencies, the National Cotton Council of America, the Association of Electric Wire Manufacturers, the National Underwriters, and other industry representatives. The Munitions Board of the Department of Defense contributed technical advice and funds to cover collection of special information for its use.

The data were collected and the report prepared by Dun & Bradstreet, Inc., of New York City, under contract with the U. S. Department of Agriculture.

Acknowledgment is made to Forrest E. Clements, formerly of the Agricultural Marketing Service, for his leadership in planning the study.

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OPINIONS AND PRACTICES OF MANUFACTURERS REGARDING FIBERS USED IN INSULATED WIRE AND CABLE

Prepared by Marketing Services Company, Division of Dun & Bradstreet, Inc., for the United States Department of Agriculture

SELECTED HIGHLIGHTS

This study was undertaken to provide a current picture of the competitive position of fibers of agricultural origin used in the manufacture of insulated wire and cable. While some information was obtained pertaining to all natural and synthetic materials used, emphasis was placed on the changing demand for the most important natural fiber used in this industry, namely cotton. The information contained in this report was obtained directly from engineers and other executives in companies manufacturing insulated electrical wire and cable.

The following observations represent a selection of the major findings of this study. They are not intended to be a complete summary of findings, but rather a guide for quick perusal.

Materials Purchased

Consumption data show that cotton in 1952 accounted for about one-tenth of the poundage of materials purchased for covering and insulating electrical wires and cables.

Almost all of the cotton purchased was in the form of yarn. The larger share of consumption was made up of plastics (vinyls in particular), rubber, and paper in various forms.

The three types of wire which accounted for the biggest usage of cotton were: power wire and cable, building wire and cable, and communication wire and cable--each one using about one-quarter of the total poundage of cotton consumed in this industry. Most of the remaining quarter was used in weatherproof and slow-burning wire and cable.

Purchasing Practices Applying to Insulating and Covering Materials

Cotton yarn is used in various applications by all of the major wire producers; without exception, they purchase their cotton yarn by specification and not by grade. The specifications developed by the American Society of Testing Materials are the ones fully acceptable to these large manufacturers. With one exception, these companies use standard tests of tensile strength, weight, amount of twist, breaking strength, type of package, and diameter.

A similar situation prevails in other yarns and fabrics, for which specification buying, the use of industry standards, and testing, are widely prevalent. Only one major wire producer buys these materials by grade.

Materials Purchased and Trends

Communication Wire and Cable

This classification is the most important type of insulated electrical wire--accounting for more than one-fifth of total sales value. These wires perform numerous functions under a wide variety of operating conditions, and this accounts for the number of different materials used to insulate and protect them. Cotton is the only natural fiber used in significant amounts in communication wire and cable, accounting for 6 percent of the total materials used. Plastics account for almost half of the materials used, and paper and rubber account for nearly all of the balance.

Cotton is used almost entirely in the form of yarn forming a braid over the insulation. In this application, industry executives almost unanimously agreed that cotton had declined in importance since World War II. The principal reasons given were the development of thermoplastic insulation, the demand for wire of smallest possible diameter, and some unsatisfactory experience in military situations.

Building wire and Cable

As in the case of communication wire, it is necessary to provide various insulations for building wire and cable to withstand widely different conditions of use.

The principal insulating and covering materials used in this classification of wire are plastics, accounting for less than half of all materials used in building wire. Synthetic rubber and paper together account for a similar amount. Cotton and fibrous glass account for most of the balance.

Cotton is the only natural fiber to enjoy extensive use as a covering. Its use is restricted, however, in that plastic-covered wires are being used without a separate outer covering. Executives reported that cotton has declined in importance since World War II in this type of wire. However, there was sharp disagreement as to whether this downtrend would continue.

Power Wire and Cable

Many insulated conductors in this classification must carry current of well over 600 volts. Thus some of these cables are 6 inches and more in diameter and are quite complicated in cross-sectional appearance. A wide range of materials is used to provide the necessary dielectric strength and long life for these expensive installations.

Cotton in one form or another is used variously as an outer covering, inner covering, a filler, and as insulation.

As an outer covering, cotton is reported being used by almost all the large power cable manufacturers, but most of them said that they have been using it less extensively in recent years--favoring in its place neoprene, asbestos, fibrous glass, nylon, and other plastics. However cotton still has special qualities which give it certain advantages over the newer materials. The principal reasons cited for the displacement of cotton were the deterioration caused by moisture absorption, bacteria, and exposure to sunlight. This raises the question as to whether research can develop techniques to enable cotton to overcome these difficulties. Neoprene appears to be cotton's strongest competitor with respect to these characteristics.

Most manufacturers reported the use of cotton as an inner covering, along with rubber, paper, and plastics. The forecast, generally, is that cotton will continue to be used in this application because of its inherent tensile strength--although several of the manufacturers report it is being displaced by plastics and by paper to some extent.

Cotton and jute are the principal materials used as fillers, imparting a smooth and uniform contour to the multiconductor power cable. In general, the market position of cotton, in this application, appears to be stable and can only be improved by a substantial price reduction relative to jute. The prime danger to cotton's present position as a filler lies in the development of multiconductor power cable in which fillers and inner and outer coverings of plastic may be accomplished in one manufacturing operation. Filler use, however, accounts for a very minor part of the total cotton used in wire manufacture.

As insulation, cotton--primarily in the form of varnished cambric--competes with saturated paper, various thermoplastics, and natural and synthetic rubber. In recent years synthetic rubbers have been improved and the use of paper has broadened. Cotton is being squeezed competitively.

Appliance Wire and Cord

These are the conductors which carry current from a wall outlet to an appliance, as well as those which distribute current within the appliance itself. Voltage requirements are generally 250 volts or less.

At one time widely used as an outside covering material over asbestos and natural rubber, cotton has declined sharply in usage in recent years. Several of the major producers have discontinued its use in favor of vinyl compounds, neoprene, and rayon. The manufacturers now using cotton say they feel the trend away from cotton will continue. Advantages claimed for the other materials are the following: Less fraying, less dirt retention, more attractive appearance, melting and reuse of scrap, lower production costs, elimination of outer covering, and elimination of filler.

Weatherproof and Slow-Burning Wire and Cable

This is the familiar wire and cable strung from pole to pole to carry electricity from local utilities to individual subscribers. In this application, cotton enjoys its greatest relative importance, accounting for almost half of the insulating and covering materials used.

Cotton is used almost entirely as an outer covering, purchased in the form of a yarn. Paper is also employed in this way, accounting for about one-fifth of the total.

In this market, as in others, cotton has been affected in recent years by the development of plastics and synthetic fibers. A continued decline for cotton is expected, unless ways are found for improving its ability to stand up under continued exposure to the atmosphere. Neoprene compounds, in particular, were reported as having greater resistance to moisture, sunlight, bacteria, and chemical fumes. Fibrous glass is used to some extent in conjunction with cotton. The glass does not retain protective saturants but does keep the cotton from deteriorating.

Automotive and Aircraft Wire and Cable

These are mostly high voltage conductors comprising ignition harness sets and cable sets for automotive and aircraft engines. The principal reason for the wide variety of insulating materials used in these applications is the widely different operating requirements of automotive vehicles and aircraft.

Plastics account for more than half of all the materials used in covering aircraft wire. Basic reasons for the importance of plastics in this connection are that Federal Government specifications require vinyl coverings because of their resistance to oil, abrasion, and moisture. Also, they must not deteriorate under the extremely high and extremely low temperature conditions found in military aircraft usage.

In automotive wires, as distinct from aircraft wires, cotton is still an important covering material, but manufacturers report that the trend is toward plastics.

Magnet Wire

This wire is used to form the coils or windings in electric motors, generators, transformers, and similar devices. Because of the space limitations inherent in the applications for this type of wire, less than one-third of its production was insulated with fibrous materials. The bulk of this production is insulated only with enamel.

Among the major wire manufacturers producing magnet wire, the most widely used natural fiber was cotton.

Trends in the use of materials to insulate this wire are clearly toward the synthetics. Both vinyl compounds and fibrous glass were expected to grow in importance. Paper seems to have the best chance of the natural materials to retain its present standing, and, to a certain extent, paper has been displacing cotton in importance. All manufacturers agree that they plan to use relatively less cotton in magnet wire in the future. However, since the demand for magnet wire has been increasing very rapidly recently, the total amount of cotton used in this application may continue somewhere near present levels during the next few years. Relative to other materials, however, its use will decline.

Other Insulated Electrical Wire and Cable

This classification constitutes a relatively small proportion of the total production of insulated wires and cables. It includes miscellaneous types of wires and cables such as mining cables, parkway cables, submarine cables, and various other special-purpose conductors, exhibiting the same trends as do those classifications discussed above.

INTRODUCTION

Every year large quantities of fibers of agricultural origin are used in the manufacture of insulated electrical wire and cable. Cotton, rubber, paper, and jute are among the natural materials which have been used in this way over a considerable period of time.

Recently, however, the competitive standing of many of these items has changed. A number of new synthetic fibers and plastics such as polyvinyl chloride, polyethylene, fibrous glass, and nylon have become available. The application of new products, moreover, has been speeded by tremendous wartime demands for wire. And in recent years new insulation problems posed by heavily loaded electrical facilities as well as inventions such as radar and television have encouraged study and experimentation with new products. As a result a list of materials used in the insulation of electrical wire today differs strikingly from any similar compilation made a decade ago.

To date there is little information available on the amounts of various fibers that are used in this industry. Even more limited is the knowledge of the extent to which natural fibers are being displaced by other materials in the insulation on electrical wires. Such information is needed, however, by the United States Department of Agriculture in order to keep abreast of the changing markets for natural fibers. In addition such research helps to stimulate and guide laboratory efforts to improve the qualities of natural fibers and so make them more useful to specific industries.

This survey was undertaken in order to provide a current picture of the usage of natural fibers in comparison with other materials in the insulation and covering of electrial wire and cable. While some information was obtained pertaining to all natural and synthetic materials used, emphasis was placed on the changing demand for the most important natural fiber used in this industry, namely cotton. Specifically the aims of this study are as follows:

1. To determine the materials which manufacturers are using currently to insulate and cover the various types of electrical wire and cable.

2. To discover opinions of manufacturers on the advantages and disadvantages of various major insulating materials in general and, where feasible, in major types of wire.

3. To determine industry trends in the use of fibers, especially cotton, and the reasons for them.

4. To ascertain the improvements which manufacturers would like to see made in the fibers which are used in this industry.

5. To determine in general the procedures followed by manufacturers in buying fibers and fabrics for use as insulating and covering materials on electrical wire and cable.

6. To assist in strengthening the market for cotton by pointing out problems in marketing which may be susceptible to solution through research.

HOW THE SURVEY WAS MADE

Definition of the Industry

The information contained in this report was obtained directly from manufacturers of insulated electrical wire and cable in the United States. It was believed that engineers and other executives of these companies could provide the most accurate and detailed account of the changing patterns of usage as well as present practices in view of their close concern with insulating and covering problems. The initial step in the survey, therefore, was to obtain a list of names of all companies in the United States who were manufacturing insulated wire and cable in 1952.

Published directories of firms in the industry were consulted and the fact that they were indeed manufacturing insulated electrical wire was established by telephone. Classified telephone directories in major cities throughout the country were also checked as a means of locating companies which did not appear on any available listing.

Companies which were drawing bare wire but not applying any insulation to it as well as firms which were engaged only in assembling electrical equipment were dropped from the list. Retailers and wholesalers of insulated electrical wire and cable similarly were excluded from consideration unless they also engaged in its manufacture.

In view of the major objectives of the survey it was decided that an additional group of insulated wire manufacturers should be removed from the list. These were the companies that manufacture magnet wire insulated only with some liquid such as enamel, varnish, or lacquer. Since these firms are seldom equipped to apply any kind of fibrous insulation it was felt that they could contribute little if anything to the study.[1]

Through these efforts a final list was compiled of 132 firms which were engaged in the manufacture of insulated electrical wire and cable in 1952, the year the study was planned.

Choosing the Sample

It was believed that useful information on most survey objectives could be obtained from detailed interviews with 10 of the largest manufacturers producing an extensive line of insulated electrical wire and cable. People in or close to the industry were consulted in the choice of these companies. Each of the firms selected agreed to participate in this study.

Most of the information in this report dealing with trends in the use of various insulating materials, the advantages and shortcomings of each, improvements desired, and company purchasing practices was obtained from executives in these companies.

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[1] Companies which manufacture magnet wire that is insulated with some type of fibrous material were, of course, included.

Information from 10 companies, however large and carefully selected, was not considered sufficient to produce an accurate picture of industry-wide consumption of insulation materials. Since volume of consumption was a major survey objective, these data were obtained from an additional 50 companies. These firms were chosen from the list of manufacturers in such a way as to insure a heavy representation of the larger companies in the sample.

Statistics on pounds of materials purchased to insulate electrical wire and cable are, therefore, industry-wide estimates based upon data received from about half of the manufacturers in the industry. The basis for the estimate is as follows:

Sales stratum[1]	Estimated number of companies in universe[2]	Number of companies in sample	Weight for projections
Over $1,000,000--------------	73	46	1.59
$500,000 to $1,000,000-------	19	7	2.71
$100,000 to $499,999---------	23	4	5.75
Under $100,000---------------	17	4	4.25
	132	61	2.16

[1] Based on manufacturers' estimates of sales volume of insulated wire.
[2] Total number of companies in the United States based on a number of sources including National Production Authority, Bureau of the Census, and industry listings.

Development of the Interview Schedules

Detailed objectives for this study were developed by the Market Surveys Section, Agricultural Marketing Service, United States Department of Agriculture; National Cotton Council; and the Marketing Services Company, Division of Dun and Bradstreet, Inc. Executives of several wire and cable manufacturers also contributed to the development of the interviewing schedules and participated as well in a pretest of these forms. Advice on technical matters relative to fibers was furnished by the former Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture. A textile chemist from this Bureau accompanied the Dun and Bradstreet analyst on some of the initial detailed interviews to be sure that technical aspects of the data were properly recorded.

Interviewing Procedure

In July 1953, a letter describing the major aims of the study was sent from the United States Department of Agriculture to the president of each company that had been included in the sample. Later, in the summer and early fall, a representative of Dun and Bradstreet, Inc., talked to each president or an executive designated by him. In these meetings the detailed objectives of the study were outlined, and questions regarding use of results were answered. In those companies were the only information requested pertained to the volume of insulating materials purchased in 1952, the interviewer was usually referred to the man responsible for company purchasing. In most instances appropriate figures were readily available from company records or were estimated by the purchasing agent without difficulty.

For the 10 companies which were asked to answer detailed questions pertaining to their present and probable future use of insulating materials, the initial interview was somewhat longer. In addition to explaining the aims of the survey, a main purpose of these meetings was to determine the names and locations of the individuals in the company who were best able to provide the desired information. The designation of the appropriate people for the Dun and Bradstreet interviewer to see was made by the company executive. Frequently he arranged specific appointments for the meetings.

Because of the complexity of the subject matter in the interviews with the 10 large companies, the same person was asked to conduct all of them. While a detailed interview schedule was prepared, many of the questions were designed to stimulate discussion. Nonsuggestive probes were used freely to develop as fully as possible the reasons for responses. As was expected, it was necessary to employ the interview schedule in a fluid way in order to adapt it to circumstances differing from one interview situation to another.

Because of the amount of information covered in the interview schedule it was found desirable in many cases to break up the interview into two or more conferences. Decisions as to the length of any meeting were left to the company executive involved. Some interviews could only be completed over a period of weeks since the appropriate executives were not all located in the same plant. At a later date in analyzing the responses some of the executives were contacted again in order to clarify earlier comments.

Response of Executives to the Interview

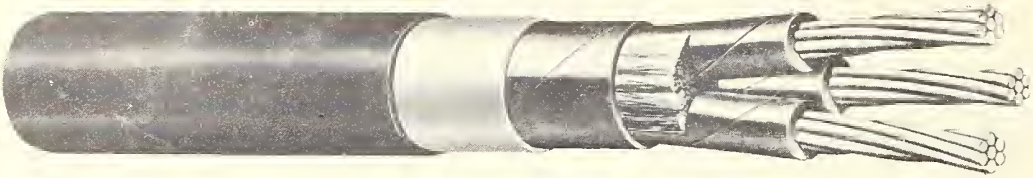
Throughout the study all executives who were interviewed contributed their time and special knowledge generously. Without their excellent cooperation this study could not have been successfully completed.

THE NATURE OF INSULATED ELECTRICAL WIRE AND CABLE

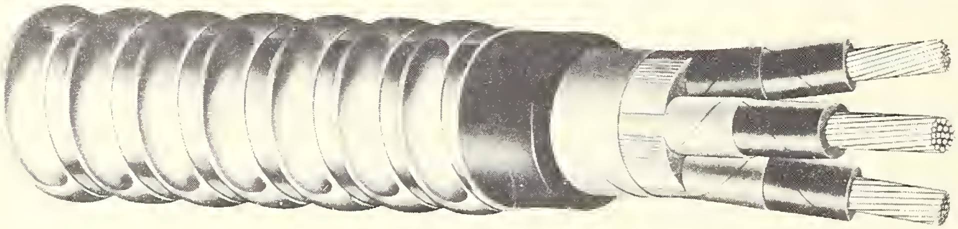
Perhaps the best known type of insulated electrical wire consists of a copper conductor encased in a rubberlike substance which is in turn covered by a braided cotton jacket. This so-called Type R wire has many familiar applications. For example, it may appear as the cord leading from the electrical appliance to the wall outlet, as the extension cord, or as the wire leading to the telephone.

There are many other kinds of insulated electrical wire, however, and some of these are not well-known. Some types have a very simple construction, for example, a single copper conductor placed in an envelope of a plastic material such as polyvinyl chloride. Others seem almost incredibly complex. Cables which are expected to carry heavy electrical voltages and perform under difficult conditions may consist of a dozen different materials or more. Figure 1 indicates the nature of a few of the complex types of cables being produced today.

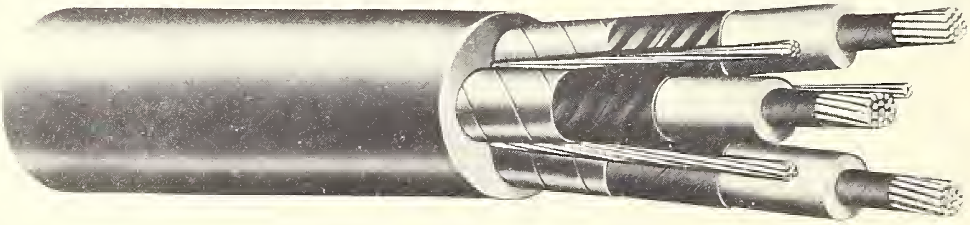
SOME COMPLEX TYPES OF INSULATED ELECTRICAL WIRE



Varnished cambric, fillers, tape, lead sheath, jacket



Varnished cambric, jute fillers, tape, thermoplastic jacket, metal armor



Butyl-base insulation, shielding, ground conductors, jacket

COURTESY OF GENERAL ELECTRIC COMPANY

U. S. DEPARTMENT OF AGRICULTURE NEG. 1345-55(1) AGRICULTURAL MARKETING SERVICE

Figure 1

The choice of the particular materials to be used in a type of wire depends upon a number of technical factors. In general, the electrical engineer considers the characteristics of each substance and its cost in relation to the performance expected of the final product. Problems of installation (Does the wire have to be placed in a conduit?) and operating conditions (Will the wire be exposed to sunny weather in use?) also have an important bearing on this matter. Among the more important matters to be considered are electric load to be carried, temperature at which the wire will operate, and exposure to the atmosphere, minerals, chemical fumes, and the like.

In some instances one product alone will satisfy all requirements. Certain thermoplastic compounds, such as polyethylene and polyvinyl chloride, often constitute the sole protective material surrounding the metal conductor. But usually the substance which serves as the dielectric must be protected from the deteriorating effects of abrasion, sunlight, and moisture by some other material. For example, wire which is insulated by rubber is usually covered by a cotton braid. The rubber keeps the electrical current in check while the cotton protects the rubber from any abuse which would shorten its useful life.

Because specific materials serve different functions in the insulation of wire, engineers classify individual items on the basis of applications. Some substances are called "insulation," others "coverings," while a third group consists of products having miscellaneous uses.

"Insulation" materials are the nonconductors. These are the substances which serve the very basic function of keeping the electrical current in check. Rubber, synthetic rubber, varnished cambric, paper, and certain plastics, such as polyvinyl chloride and polyethylene, are among the important items in this classification.

"Coverings" include the various materials which protect the "insulation" from the deteriorating effects of abrasion, sunlight, moisture, fire, chemical fumes, oils and the like. In multiconductor cables a separate covering is placed over each insulated conductor primarily to minimize abrasion. Later the several cables are further covered to resist the deleterious activity of external agents. Cotton, glass yarn, jute, sisal, rayon, asbestos, neoprene, nylon plastic, lead, and steel are among the numerous covering materials used. Wherever a fibrous covering is employed it is customary to apply some saturant such as lacquer, varnish, or paraffin for additional protection against the elements.

Some materials perform still other functions in insulated wire and cable. The bare metal conductor is sometimes wrapped with a paper, cotton or cellophane tape "separator" before any insulation is applied. This allows for easy splicing when untinned conductors are used.

Multiconductor cables, moreover, require "fillers" which round out the cable and fill the interstices. Jute, cotton, paper, rubber, and plastics are among the materials used for this purpose. In the construction of these cables some material must also be used to bind together the several conductors prior to the application of the outer covering. A metallic or paper tape is commonly used for this purpose.

MATERIALS PURCHASED--TOTAL BY TYPE OF WIRE

This section of the report is based on data received from almost half of the manufacturers in the industry. The volume figures and percentages are, therefore, industry-wide estimates.

For all types of insulated wire and cable included in this survey, plastics accounted for more than one-third and rubber for one-fourth of the consumption of all fibers and materials reported. Paper and cotton came next, with 16 and 11 percent, respectively. (See table 1.)

TABLE 1.--Estimated quantity and percentage of selected covering and insulating materials purchased for the manufacture of electric wire and cable in 1952

Material	Types of insulated wire and cable																	
	Communication wire and cable		Magnet wire[1]		Weatherproof and slow-burning wire and cable		Building wire and cable		Power wire and cable		Appliance wire and cord		Automotive and aircraft wire and cable		All other types		Total	
	1,000 lb.	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb.*	*Percent*	*1,000 lb,*	*Percent*
Acetate	2,602.5	2	51.1	2	--	--	--	--	17.4	(2)	47.0	(2)	4.7	(2)	31.3	1	2,754.0	1
Asbestos	731.6	1	7.0	(2)	--	--	--	--	6,907.4	8	2,985.9	7	--	--	110.6	4	10,742.5	3
Cotton	9,651.0	6	1,419.5	43	7,901.0	46	10,029.4	9	10,783.2	12	2,494.4	6	2,062.9	22	926.9	29	45,268.3	11
Fibrous glass	602.5	(2)	943.3	28	147.4	1	7,483.2	7	628.3	1	188.2	(2)	182.8	2	7.0	(2)	10,182.7	2
Jute	4,448.9	3	--	--	58.7	(2)	963.7	1	7,702.5	8	2,550.3	6	7.0	(2)	31.2	1	15,762.3	4
Linen cord	4.6	(2)	--	--	--	--	--	--	--	--	5.2	(2)	3.2	(2)	--	--	13.0	(2)
Paper	35,470.6	23	751.4	23	3,514.9	21	18,333.7	17	11,783.9	13	393.1	1	168.2	2	.4	(2)	70,416.2	16
Plastics	72,341.2	47	123.8	4	3,758.5	22	43,327.9	41	19,682.3	21	13,751.0	32	4,864.9	53	1,645.9	52	159,495.5	37
Rayon yarn	498.3	(2)	--	--	--	--	165.2	(2)	32.3	(2)	539.8	1	64.0	1	44.9	2	1,344.5	(2)
Orlon yarn	--	--	1.1	(2)	--	--	--	--	--	--	--	--	--	--	--	--	1.1	(2)
Silk yarn	2.4	(2)	9.1	(2)	--	--	--	--	--	--	--	--	--	--	5.2	(2)	16.7	(2)
Rubber	28,196.4	18	--	--	1,634.0	10	23,949.9	22	33,475.0	36	19,413.4	46	1,850.9	20	358.8	11	108,878.4	25
Sisal	--	--	--	--	--	--	2,738.8	3	1,270.7	1	210.7	1	--	--	--	--	4,220.2	1
Total	154,550.0	100	3,306.3	100	17,014.5	100	106,991.8	100	92,283.0	100	42,579.0	100	9,208.6	100	3,162.2	100	429,095.4	100

[1] Manufacturers of magnet wire that insulate only with plastics or with liquids such as enamel, varnish, or lacquer were not included in the sample.

[2] Less than 1 percent.

Of the fibers and materials reported for insulation, the greatest quantity went into communication wire and cable, with building wire and cable and power wire and cable next in volume. Appliance wire and cord, weatherproof and slow-burning wire and cable, automotive and aircraft wire and cable, and magnet wire followed in that order. All other types of insulated wire and cable accounted for less than 1 percent of the total pounds of insulating material purchased by this industry.

Types of insulated wire and cable	Percentage of insulating material purchased
Communication	36
Building	25
Power	21
Appliance	10
Weatherproof and slow-burning	4
Automotive and aircraft	2
Magnet	1
Other	1
Total	100

For communication wire and cable, plastics were purchased in greatest volume, accounting for almost one-half of the total insulation material used. Paper ranked next, with less than one-fourth, and rubber followed with less than one-fifth. Of the 72 million pounds of plastic material purchased by this division of the industry, two types--polyethylene and vinyl compound--were used in about equal quantities and together accounted for 94 percent. Of the 35 1/2 million pounds of paper purchased, almost 60 percent was in paper pulp, and 40 percent in untreated paper. Of the 28 million pounds of rubber purchased, almost 90 percent was synthetic. The rest was natural rubber. (See table 2.)

For building wire and cable, the three most important insulating materials were plastics, rubber, and paper, in that order. Plastics accounted for a little more than two-fifths, rubber for more than one-fifth, and paper less than a fifth of all materials purchased. The plastic was almost entirely vinyl compound, and the rubber was almost all synthetic. Slightly more than half of the paper was treated.

Materials purchased for insulated power wire and cable were somewhat more evenly distributed among the various fibers. Rubber accounted for a little over a third of the total, plastics one-fifth, and paper and cotton over a tenth each. Almost 90 percent of the rubber purchased was synthetic; vinyl compound was the most important plastic.

For appliance wire and cord, almost half the insulating material purchased was rubber. Almost a third was plastic. More than 85 percent of the rubber was synthetic, and vinyl compound was by far the most important plastic.

In weatherproof and slow-burning wire and cable, cotton was again the leading fiber, followed by plastics and paper. Almost all the cotton purchased was in the form of yarn. Of the 3 3/4 million pounds of plastics purchased, almost three-fourths was polyethylene; the remainder was vinyl compound. All the paper purchased was untreated.

Plastics accounted for over half the insulating materials purchased by the manufacturers of automotive and aircraft wire and cable. Cotton and rubber, which were purchased in about equal volume, accounted for more than 40 percent of the total. Here too vinyl compound was the plastic most used. Almost two-thirds of the cotton consumed by this branch of the industry was in the form of yarn and more than one-fifth was cotton braid. Of the rubber purchased, three-fourths was synthetic and one-fourth natural.

TABLE 2.--Percentage of selected covering and insulating materials purchased for the manufacture of electric wire and cable, by class of material, 1952

Class of material	Types of insulated wire and cable								
	Communi-cation wire and cable	Magnet wire[1]	Weather-proof and slow-burning wire and cable	Building wire and cable	Power wire and cable	Appliance wire and cord	Automotive and air-craft wire and cable	All other types	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
ACETATE:									
Yarn	100	100	--	--	--	78	4	26	98
Untreated tape	(2)	--	--	--	88	22	--	74	2
Varnished tape[3]	(2)	--	--	--	12	--	96	--	(2)
Total	100	100	--	--	100	100	100	100	100
Thousands of pounds	2,602.5	51.1	--	--	17.4	47.0	4.7	31.3	2,754.0
ASBESTOS:									
Filaments, rovings, yarn	99	83	--	--	79	99	--	100	86
Paper tape	--	--	--	--	18	1	--	--	12
Tape	1	17	--	--	3	--	--	--	2
Sleeving and tubing	--	--	--	--	--	--	--	--	--
Total	100	100	--	--	100	100	100	100	100
Thousands of pounds	731.6	7.0	--	--	6,907.4	2,985.9	--	110.6	10,742.5
COTTON:									
Raw	--	--	--	(2)	(2)	--	--	--	(2)
Braid	(2)	--	--	--	--	15	22	--	2
Yarn	95	100	100	92	47	84	63	35	81
Cord or twine	(2)	--	(2)	--	6	1	--	--	1
Untreated tape	4	--	(2)	4	14	--	11	--	6
Varnished tape[3]	(2)	--	--	1	24	(2)	(2)	--	6
Plastic tape[3]	(2)	--	--	--	--	--	--	--	(2)
Processed cotton	1	--	--	--	--	--	--	--	(2)
Neoprene tape[3]	--	--	--	--	1	--	--	--	(2)
Rubber filled cotton tape[3]	(2)	--	--	3	8	(2)	(2)	65	4
Vinyl tape[3]	--	--	--	--	(2)	--	4	--	(2)
Total	100	100	100	100	100	100	100	100	100
Thousands of pounds	9,651.0	1,419.5	7,901.0	10,029.4	10,783.2	2,494.4	2,062.9	926.9	45,268.3
FIBROUS GLASS:									
Filaments, chopped strands, rovings, yarn	90	100	100	97	78	100	99	100	96
Untreated tape	3	--	--	--	5	--	(2)	--	1
Varnished tape[3]	7	--	--	--	11	--	1	--	1
Bonded cord, plastic glass	--	--	--	--	6	--	--	--	(2)
Paper, fibrous glass[3]	--	--	--	3	--	--	--	--	2
Total	100	100	100	100	100	100	100	100	100
Thousands of pounds	602.5	943.3	147.4	7,483.2	628.3	188.2	182.8	7.0	10,182.7
PAPER:									
Untreated	40	64	100	45	88	65	85	100	53
Treated	2	36	--	55	10	35	15	--	18
Paper pulp	58	--	--	--	--	--	--	--	29
Cable paper filler	--	--	--	--	2	--	--	--	(2)
Total	100	100	100	100	100	100	100	100	100
Thousands of pounds	35,470.6	751.4	3,514.9	18,333.7	11,783.9	393.1	168.2	.4	70,416.2
PLASTICS:									
Kel-F, Teflon	(2)	--	--	--	2	--	1	2	1
Nylon:									
Yarn	(2)	98	--	--	(2)	(2)	(2)	(2)	(2)
For extrusion	6	2	--	--	(2)	(2)	5	3	3
Polyethylene	47	--	72	(2)	15	3	12	13	25
Silastic	(2)	--	--	--	(2)	--	2	9	(2)
Vinyl compound	47	--	28	100	83	97	80	73	71
Total	100	100	100	100	100	100	100	100	100
Thousands of pounds	72,341.2	123.8	3,758.5	43,327.9	19,682.3	13,751.0	4,864.9	1,645.9	159,495.5
RUBBER:									
Natural	12	--	--	2	11	12	25	29	9
Synthetic	88	--	100	98	89	86	75	71	90
Reclaimed	(2)	--	(2)	(2)	(2)	2	--	--	1
Total	100	--	100	100	100	100	100	100	100
Thousands of pounds	28,196.4	--	1,634.0	23,949.9	33,475.0	19,413.4	1,850.9	358.9	108,878.4

[1] Manufacturers of magnet wire that insulate _only_ with plastics or with liquids such as enamel, varnish, or lacquer were not included in the sample.
[2] Less than 1 percent.
[3] Adjusted to eliminate weight of material other than fiber or fabric involved.

Cotton, all of it in the form of yarn, was the material most used for insulation of magnet wire,[2] accounting for somewhat less than half of the total. Fibrous glass and paper were next in importance. The fibrous glass purchased for this purpose was in the form of filaments, chopped strands, rovings, and yarn. Almost two-thirds of the paper was in treated form and the rest untreated.

Of the 3 million pounds of material purchased for insulation of other types of insulated electric wire and cable, plastics and cotton were the most important. Although all of the major types of plastics were purchased, vinyl compound accounted for almost three-fourths of the total. Only two types of cotton were purchased--rubber-filled cotton tape and cotton yarn. The tape constituted about two-thirds of the total weight of cotton consumed in these end products.

TRENDS IN THE USE OF NATURAL FIBERS

The 52 insulating engineers, purchasing agents, and other executives of the 10 companies which were interviewed at length in this survey all stated, that cotton and most other natural fibers have been losing out in the wire and cable industry. Natural rubber has been displaced in large measure by the cheaper synthetic product. Asbestos, once of prime importance for its heat-resisting attributes, has seen part of its market shift to the noninflammable, cheap fibrous glass. Silk, once of some importance in this industry, has been largely displaced by cheaper and more serviceable materials. Jute, too, plays a minor role today as a filler and, sometimes, as a braided covering. Only paper, thanks to the development of new types, is retaining and perhaps improving its position. Its high dielectric strength per unit of thickness makes it especially valuable as insulation for high-voltage power cable.

Cotton still retains much of its former position when employed as tape, impregnated with varnish, in what is known as varnished cambric insulation. It is also widely used as a covering but in this function, all executives agreed, cotton has been losing position. The extent of cotton's decline is obscured by figures showing only total consumption of this material in recent years. Total production of insulated electrical wire and cable has risen rapidly in the past decade. Cotton has not grown in importance to the same degree.

The records of one company portray the declining importance of cotton. It should be pointed out that this company has not moved into plastics as fast or as far as many of its competitors. As a result the data given below shows a more favorable cotton situation than would be shown by many other firms. Below are the percentages of cotton relative to all materials used in the insulated wire manufactured by this firm over a period of years.

But while cotton has been losing ground in this industry, engineers disagreed as to the reasons. Superior properties of plastics such as polyethylene and polyvinyl chloride were advanced as a major reason by some executives. Others commented on the improvements in their products when neoprene, nylon, or fibrous glass were used in place of cotton. Executives of 8 companies attributed this trend largely to the price situation.

The reasons for the declining use of cotton and other natural fibers can best be understood when the various major types of wire are analyzed separately. Indeed divergent trends in the application of natural fibers become evident in such a presentation. The hundreds of different types of wire have been grouped into the following 7 classes for this purpose:

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[2] Only those companies which used some fiber in insulation were included in the sample. Companies that insulate only with plastics or with a liquid such as enamel, varnish, or lacquer were not included.

Changing Importance of Cotton as an insulating material in the production of a specific wire producer
(1945-1952)

Year	Gross shipments of completed wire	Pounds cotton consumed	Cotton percent total materials
	(1945 = 100)	(1945 = 100)	*Percent*
1945----------------------	100	100	9.3
1946----------------------	85	98	10.6
1947----------------------	174	193	10.3
1948----------------------	172	195	10.5
1949----------------------	121	116	8.9
1950----------------------	145	138	8.8
1951----------------------	166	130	7.3
1952----------------------	174	122	6.5

Communication wire and cable
Building wire and cable
Power wire and cable
Appliance wire and cord
Weatherproof and slow-burning wire and cable
Automotive and aircraft wire and cable
Magnet wire

TRENDS BY TYPE OF WIRE

Communication Wire and Cable

Scope and Importance

Communications wire and cable includes those insulated conductors which are used in sound and picture transmission and in the operation of signals. These wires perform numerous functions under a wide variety of operating conditions. A listing of some well-known types reveals the range of applications--telephone wire, switchboard cable, railroad signal wire, coaxial cable, and circuits in radio and television sets.

According to the 1947 Census of Manufacturers' Sales, the various types of communications wire and cable, including signal wire, accounted for slightly over one-fifth of total sales--valued at $194,412,000--of insulated electrical wire in 1947. No other class of wire was of greater importance at that time. Without question this type of wire is of at least equal significance today. In fact, developments in the communications field, particularly television, in recent years suggest that this class of wire may well be of even greater importance at the present time.

Materials Used

Some communications wire is designed for indoor use, but much of it is exposed to the deteriorating effects of sunlight and moisture. Still other types are buried in the ground or operate under water. Military signal wire must withstand perhaps the greatest abuse, as it lies on the open terrain under combat conditions.

The wide variety of operating conditions as well as applications for this type of wire accounts for the number of different materials which are used to insulate and protect it (table 1).

Trends in Use of Natural Fibers

Cotton is the only natural fiber used to any important extent as a covering for communications wire and cable. Eight of the 10 large companies manufacture some wire of this type and all but one of them use cotton for this purpose. The other firm uses nylon plastic.[3] The cotton is typically applied as yarn which forms a braid over the insulation. In some instances, however, the yarn may be wound continuously around the dielectric material in what is known as a ''serving.''

In 6 of the 7 firms which use cotton to cover communications wire, cotton has declined in importance in this application since World War II. Executives of the other firm stated that cotton had "held its own" in this use so far as their output was concerned. All these firms, however, expressed the opinion that in the next 5 years cotton would continue to decline in importance as a covering material.

A number of reasons were advanced for this trend. The development of thermoplastic insulation, the demand for wire of smallest possible diameter, and certain military experiences with cotton were the major factors cited.

Development of Thermoplastic Insulation

Executives of all 10 companies agreed that the introduction of certain plastics, notably polyvinyl chloride and polyethylene, into the industry in the last decade has had a profound effect. These products possess a number of very useful properties not found in natural or synthetic rubber compounds. They are highly resistant to moisture, ozone, most chemicals, and oil. Moreover, they will not support combustion.

But from the standpoint of cotton the most significant of their attributes is the ability to resist abrasion. They are sufficiently "tough" to warrant their use without any additional covering whatsoever. Other commonly-used dielectric materials require the application of a cover such as cotton to protect them from wear and tear.

Wire and cable manufacturers have found it relatively easy to produce wire with plastic insulation. These new compounds are mixed, handled, and extruded in much the same way as rubber. Moreover, there was some incentive to shift to them since the production process could be simplified. Braiding machines could be eliminated.

Cotton, and other materials used as coverings on communications wire, have, therefore, experienced a declining demand because the use of separate coverings has itself diminished.

Demand for Wire of Smallest Possible Diameter

A desire for wire of smallest possible diameter in relation to the electrical load carried has also hurt cotton's position. Some types of communications wire are installed in very limited space. The wiring in switchboards and in radio and television sets are examples. In the words of one engineer ''In switchboard cable, space is an important factor--the diameter of each conductor should be as small as possible consistent with the function it is to perform. Polyvinyl chloride, by eliminating the need for an outer jacket entirely, permits the use of a wire of less diameter than the cotton and rubber type.''

Wherever space is a problem wire with a separate insulation and covering is at a disadvantage compared to the new, thinner, plastic type.

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[3] Nylon is applied in the wire and cable industry in the form of yarn and as a plastic which is extruded over the wire insulation. To avoid any confusion as to form, the term "nylon plastic" will always be used whenever reference is made to the extruded-type product.

Military Experience With Cotton-Covered Wire under Certain Storage Conditions

Companies which were manufacturing signal wire for military use reported substantial declines in the use of cotton. During World War II, according to insulating engineers at several companies, cotton was used in large quantities to cover the enormous amounts of military signal wire needed. Cotton, however, absorbs moisture and a wet braid cuts down talking distance and contributes to cross talk. Moreover, at the start of the Korean action, the Army found that under certain storage conditions much of its cotton-covered wire had rotted.

Specifications for military signal wire have since been revised. Replacing the rubber insulation and cotton covering are polyethylene insulation protected by a nylon plastic jacket. The advantages of nylon plastic coverings were summarized by one engineer as follows:

> "Nylon is much more abrasion resistant than cotton. This is a vital factor when wire is used up front under difficult conditions. Nylon also resists absorption of moisture better than cotton, although it is not perfect in this respect. And nylon, in combination with polyethylene makes possible a lighter wire of smaller diameter than rubber and cotton. This is especially desirable when wire is to be transported by plane".

Building Wire and Cable

Scope and Importance

Most electrical conductors which are installed in or on public and private buildings of all kinds are termed building wire and cable. These are the wires which bring electricity from the poles or conduits of the electrical utility to the wall plugs and lighting fixtures in home, factory, and office. Telephone wires and wires which lead from wall outlets to various electrical appliances are not included in this classification for purposes of this report. The former were discussed under the heading of communications wire and cable while the latter are treated elsewhere under the heading: Appliance Wire and Cord.

Some building wire and cable, when installed, is exposed to the weather. Other cables are placed in raceways in walls of buildings or under-ground. As with communications wire, it is necessary to provide various insulations to withstand widely different conditions of use. Some types of building wire are very moisture-resistant; others are less so. Some are designed to inhibit the deteriorating action of various chemical fumes, acids, and oils. Specifications for each of the various types are set forth in the standards of Underwriters' Laboratories and the industry produces building wire and cable to meet or exceed these conditions.

In 1947, building wire and cable valued at $174, 003, 000, was second only to communication wire and cable on the basis of value of goods shipped. According to the Census, over 19 percent of all insulated electrical wire and cable produced in that year was in this classification. The insulating materials which were used in the production of this wire in 1952 are shown in table 1.

Trends in Use of Natural Fibers

As in the case of communications wire, cotton is the only natural fiber to enjoy extensive use as a covering. Six of the ten large companies were producing one or more types of building wire and cable in 1952, and all six indicated that they were using cotton. A number of other products, however, were also being used in this way. Fibrous glass and rayon were competing fibrous coverings and galvanized steel and lead were being employed where extreme protection from moisture was desired. Polyvinyl chloride and neoprene were also being used without a separate outer covering.

Executives of all six building wire producers stated that cotton had lost stature as a covering on this type wire since World War II. There was a marked difference of opinion, however, as to the likelihood of its further displacement. Engineers in one firm expressed the belief that cotton usage had dropped about as much as it would in this application. In another firm, however, the engineers felt that cotton would virtually disappear as an outer covering of this type of wire in the next 10 years. Executives of the other four firms expressed opinions which fell between these extremes. In general, it appears that cotton has already lost heavily in this market, particularly in the wires of small diameter used in residential dwellings. In wire of larger diameter--used in commercial buildings--cotton is still an important factor.

One company has even installed new braiding machines to produce the covering for these wires. Engineers in this firm expressed the belief that little if any cotton would be used in wire of size 10 or smaller but that cotton would be the dominant fibrous covering on the larger sizes. The reason for this statement as well as the explanation of cotton's declining role in this market lies in certain recent trends.

Demand for Wire of Smallest Possible Diameter

The desire for insulated wire of smallest possible diameter has affected the choice of materials for most types of wire in recent years. Nowhere is this need greater than in the case of building wire, according to the engineers. In drawing plans and specifications for new residential and business structures, architects allow space sufficient to meet present and anticipated future needs for electrical wiring. In recent years, however, the demand for electricity has grown far more rapidly than was expected. In the home, for example, the television set, food freezer, and the air conditioner increase the electrical load which the building wire must carry. As a result there is a need for more wires in space which may be inadequate. One answer is rewiring with new wire which will carry the same load as the old but is smaller in diameter. More wires may then be placed in the raceways.

Pressure for minimum wire diameter comes from still another direction in the case of building wire which is sheathed in steel. The most expensive component in this type of wire is the metal which serves as the outer covering. If thinner insulation and covering can be applied to each individual conductor in such wire, the circumference of the circle to be housed in steel is reduced. This, of course, means that less steel is needed per foot of wire. The savings possible, in view of the price of steel, are greater than might be anticipated.

This trend in wire diameter works against the use of cotton coverings on building wire. Various other materials such as polyvinyl chloride, neoprene, fibrous glass, and rayon permit the manufacture of wire of smaller diameter than the corresponding rubber insulated, cotton braided type. This end is accomplished through either a reduction in the thickness of the braid or the complete elimination of separate coverings.

A specific example may help to show the extent of cotton's disadvantage. The following tabulation presents certain dimensions of several popular sizes of building wire produced by one manufacturer. It will be noted that the over-all diameter of the Type R wire which uses cotton exceeds in all cases the diameter for the corresponding Type T (thermoplastic insulated-no cotton) wire. For example, in Number 14 wire, the conductor has a diameter of 0.064 inches. When protected by rubber and cotton the over-all diameter becomes 0.151 inches. But when thermoplastic (polyvinyl chloride) insulation is used, which requires no cotton, the diameter increases to only 0.131 inches.

While a difference of 0.020 inches may seem infinitesimal, this is of some moment where several conductors are involved. Moreover, in this industry very slight variations are important. "Differences of even a few mills are very significant in this business" according to most of the engineers interviewed.

A comparison of overall diameters of selected rubber and thermoplastic insulated building wires[1]

Conductor size	Overall diameter in inches			Space saved by use of thermoplastic insulation in inches
	Diameter of wire conductor in inches	Type R rubber insulation single cotton braid	Type T thermoplastic insulation no braid required	
American Wire Gauge.				
14----------------------	0.064	0.151	0.131	0.020
12----------------------	.081	.167	.148	.019
10----------------------	.102	.220	.168	.052
8----------------------	.128	.279	.228	.051

[1] All wires have solid conductors.

Power Wire and Cable

Scope and Importance

Insulated conductors which carry electricity to operate machinery are classed as power wire and cable. In some cases these cables are designed for low voltages but many are insulated for well over 600 volts. In appearance they differ considerably from the layman's concept of electrical wire. Some types are six inches and more in diameter and consist of several conductors, separately insulated and bound together under an impervious sheathing. A wide range of materials is used to provide the necessary dielectric strength and long life for these expensive installations.

Census data for 1947 values the production of power wire and cable at $124,351,000. This figure represents 13.9 percent of the total production value of insulated electrical wire. However, it includes an unspecified amount of varnished cambric insulated wire which was used as building wire.

Trends in Use of Fibers

The wide range of voltage which must be handled by power cable and the frequent incorporation of several conductors in one sheathing make for the use of virtually all insulating and covering materials on this type of wire. Cotton in one form or another and several of the other materials are used variously as an outer covering, inner covering, a filler, and as insulation. Consequently appraisal of trends must deal separately with each form of application.

Outer Covering Materials.--The materials used as outer covering are braided cotton, lead, neoprene, and other forms of synthetic rubber; asbestos, glass fibers; and plastics such as nylon, vinyl compound, and polyethylene. Some rayon and acetate are also used. Cotton is flexible, strong for its cost, and will withstand high temperatures which melt or mar rubber and plastics. However, it deteriorates more rapidly than many of the competitive materials because it absorbs moisture and is affected by bacteria and long exposure to the sun.

It is used as an outer covering by 8 of the 9 large manufacturers making power cable, but 6 of the manufacturers report that they have been using it less extensively in recent years. The other 2 characterize its recent position as static.

Neoprene has become the most widely used outer covering material because of its greater resistance to acids, moisture, decay, and sunlight.

There are, however, some particular situations in which cotton continues to be a necessity:

1. In motor manufacture the final baking process involves temperatures which are too hot for neoprene and plastics.

2. Certain diameters are too large for neoprene extrusion machinery.

3. Transformer use often subjects cable to sharp twists which would break glass, and to heat which would melt vinyl compound.

As far as can be foreseen, outer coverings will continue to be needed on power cable, but the wire and cable industry expects that the trend to a more limited use of cotton will continue. Much of the effect, however, has presumably been felt by the present time.

Inner covering.--The inner covering is used to hold together the several conductors usually present in power cable, and the need for this application will presumably remain constant. The materials used are cotton, rubber, paper, and plastics (as filaments and in an extruded form).

Cotton is used to some extent by 7 of the 9 concerns contacted on this product. Four companies report that the material is holding its own in this use. Two of the three which are using less cotton now than formerly are using plastic insulated wire to a greater degree and use a plastic inner cover. The third reports cotton as losing out gradually to paper in its operations. Two factors contribute to the continued use of cotton as an inner covering--its inherent tensile strength and its use as a backing on rubber or plastic tape used as an inner covering.

Fillers.--Fillers impart a smooth and uniform contour to the mulitconductor filled power cable. Cotton and jute are the principal materials used for this purpose. The chief advantages of the former are its smaller bulk and greater flexibility. It is thus a must where diameters are relatively small. Jute on the other hand has a better "feel" and is substantially cheaper than cotton. In total the market position of cotton in this application appears to be stable and can only be improved by a substantial price reduction. Six of the nine large manufacturers use some cotton as a filler, and five of them report that cotton is holding its own.

The prime danger to cotton's present position as a filler lies in the development of fully extruded multi-conductor power cable in which fillers, and inner, and outer coverings of plastic may be accomplished in one operation. The limiting factors in this area are the size of the diameter which may be handled in present extrusion equipment, and the fact that the final application of the wire must permit the use of the plastic as an outer covering. In the final analysis, however, filler use accounts for a very minor part of the total cotton used in wire manufacture.

Insulation.--In this application cotton--primarily in the form of varnished cambric--competes with a saturated kraft paper, various thermoplastics, and natural and synthetic rubber. Traditionally, rubber has been used where possible because of its low cost. Paper has been used where its dielectric properties required its use in spite of the more costly outer covering which must be used with it.

Rubber, however, for many years could not handle conditions beyond the low voltage range, and paper was not used in the medium voltage range. This left the medium voltage range as the special preserve of varnished cambric. In recent years, however, synthetic rubbers have been improved, and paper use has broadened. Cotton has consequently been squeezed. With paper and rubber both qualitatively more competitive, their lower cost places cotton at a disadvantage where its performance is equivalent. Two additional restraining factors are present in the situation--the trend toward higher voltages in power cable use (this increases the reliance on paper) and the encroachment of plastics. On the positive side, cotton maintains one advantage--it is easier to splice than paper and, if an installation involves many terminals, it will presumably be used to as great an extent as voltage requirements will permit.

All but 1 of the 9 large manufacturers reporting on this wire type use varnished cambric. Four feel that its present position is about as it has been in recent years, and four see its position as one of declining importance. Subjectively, the weight of opinion would seem to be on the down side, and the factors involved suggest that the decline should continue and may well be accelerated.

In summary, the consumption of cotton in power wire and cable manufacture is in a declining trend. On an overall basis total use should continue to decline gradually, but at any time a radical development in the use of plastics may seriously reduce the market share still held by cotton.

Appliance Wire and Cord

Scope and Importance

This product area includes wiring which carries current from a wall outlet to an appliance, as well as wire which distributes it within the appliance itself. Cords are generally 6 feet in length and incorporate an attachment plug or cap. Voltage requirements are usually 250 volts or less. The wiring within the appliance may, of course, utilize very short lengths of wire.

Production of wire for these purposes in 1947 was valued at $48,752,000. This represented 5.4 percent of the total value of wire production. More than two-thirds of this total was flexible cord.

Trends in Use of Fibers

At one time widely used as an outside covering material over asbestos and natural rubber, cotton usage has declined in recent years. A few of the important producers contacted have discontinued its use entirely and several others said they expect to take similar action.

In cords cotton has yielded to vinyl compound, neoprene, and rayon. The first two, of course, require no outer covering. The rayon has a greater eye-appeal, is reputedly stronger and cheaper for equal quality.

Seven of the ten major manufacturers interviewed in detail make wire for these applications. Two of the seven have abandoned the use of cotton, and the other five report its use as declining. Several manufacturers speak of the revolution in material use that has occurred in this area as a completed fact in 1953. Others see the virtual end of cotton as not far distant.

Reasons for Changes in Materials Used

The major shift in this application has been to polyvinyl resin and neoprene. These two materials accounted for an estimated two-thirds of the material used.

The vinyl is used where flexing is not a serious problem. Its advantages over cotton, as reported by executives, are: (1) It does not fray, (2) it does not retain dirt, (3) it is attractive in appearance, (4) scrap can be melted and re-used, (5) production costs are lower, (6) insulation and outer covering are one, and (7) no filler required.

Neoprene incorporates some of the same production cost advantages and meets the flexing demands of the products with which the wire is used in most cases.

Cotton continues to be used where low outside temperatures may be a factor, and by some manufacturers who have not yet replaced it with neoprene where flexibility is necessary--in iron cords for example.

The two quotations following reflect the opinion of the engineers of two important cord manufacturers.

> "Declining rapidly. Polyethylene and polyvinyl cholride provide a much more attractive type wire which does not fray. It has very largely replaced the older rubber compound covered with a braid of cotton. Plastic wire without a fibrous covering is competitive in price and desired by consumers. Moreover, with plastics our scrap problem is minimized--any deficient or defective wire can be reused since vinyl can be melted down and extruded again. This can't be done, of course, with cotton."

> "Declining in importance. Thermoplastic insulation, because of attractive appearance over a long life, is replacing cotton on the cords attached to appliances. Cotton frays and presents a poor appearance after a time. Cotton, moreover, becomes dirty and, therefore, unattractive to the housewife. Cotton is still used and preferred to any present plastic where the use of the appliance requires considerable flexing of the wire. For example, the cord attached to an electric iron is subject to considerable flexing while ironing. Cotton will withstand this, but thermoplastics will crack and deteriorate. One of cotton's major advantages in general is its very flexible character. The other is its strength."

Weatherproof and Slow-Burning Wire and Cable

Scope and Importance

Weatherproof and slow-burning wire is the familiar wire and cable which is strung from pole to pole to carry electricity from the local public or private utility company to subscribers. In the process of manufacture, the protective covering is so impregnated and finished as to make the wire resistant to flames as well as the weather. The American Standards Association has established a specification for this type of wire and prescribes certain tests to determine the acceptability of wire produced by various manufacturers.

Census data for 1947 values the production of weatherproof and slow-burning wire and cable at $76,256,000. Eight and one-half percent of all wire shipped in 1947 fell into this classification.

Of all the insulating and covering materials used for weatherproof and slow-burning wire in 1952, almost half was cotton yarn. Plastics (mostly polyethylene) and untreated paper each accounted for about one-fifth, and synthetic rubber represented most of the remaining one-tenth (tables 1 and 2).

Trends in Use of Fibers

Six of the ten large wire and cable producers that were interviewed manufacture weatherproof wire. All six reported that cotton was used as a covering on some of their output. The only other natural material which was employed in this way was paper. One company reported using a limited amount of paper.

Four producers also use neoprene and polyethylene, and two are experimenting with fibrous glass. Other synthetic fibers such as Dacron and Orlon were also in the process of evaluation. One company was using rayon as a covering on some weatherproof wire at the request of a few customers.

In this market, as elsewhere in the wire and cable industry, cotton has felt the effect of mounting competition in recent years from plastics and synthetic fibers. All five manufacturers of weatherproof wire agreed that cotton had been declining in importance as a covering on such wire. In some firms this decline has been substantial; in others, modest. One engineer summed up recent changes in this manner:

> "Five years ago nearly all outer protection was cotton with a saturant. Today neoprene and polyethylene are becoming favorites. Vinyl is also specified by some customers. Glass is being used in conjunction with cotton and by itself too, experimentally."

Deficiencies of Cotton

The primary reason for the shift away from cotton as a covering on weatherproof wire is this fiber's inability to stand up when exposed to the atmosphere. Despite the fact that a water insoluble saturant is applied to it and a final finish including mica flakes and a mineral filler is used, cotton absorbs moisture and rots. Sunlight and bacteria also shorten the useful life of this fiber while the acid fumes in the air near certain manufacturing centers take a very serious toll of any cotton-braided weatherproof wire in the vicinity. When the fiber deteriorates, sections of the covering hang down from the wire conductor in streamers. This difficulty is known as "festooning."

Important Properties of New Products

As long as no better material was available at a reasonable price, cotton was used extensively in this type of wire. A number of new plastics and synthetic fibers, however, offer superior properties at a price which encourages their use. Neoprene compounds have high resistance to moisture, sunlight, bacteria and chemical attack. Polyethylene too provides better protection from the elements and is preferred to neoprene by some manufacturers. Vinyl compounds, however, have made relatively little headway in this market, probably because they are somewhat less resistant to moisture than other new materials.

The properties of glass fiber are such as to reduce the use of cotton while at the same time perpetuating its application in smaller amounts. Glass is highly resistant to chemical attack and does not festoon as readily as cotton. On the other hand, engineers report that fibrous glass will not absorb non-conducting saturants. For this reason, companies have turned to glass-cotton blend as a covering. Cotton is retained as an inner braid for its ability to absorb saturants while glass is used in the outer braid to minimize deterioration of the covering through action of the elements and chemical fumes.

Glass, then does not completely displace cotton when it is used to cover this type of wire. Neoprene and polyethylene, of course, eliminate the need for any cotton or other fibrous material since they serve as both an insulation and a covering.

The Importance of Costs

Throughout the survey, engineers stressed the importance of price of materials and manufacturing costs. Very small differentials in price per pound or per foot loom large when wire is purchased in very large quantities.

Nowhere was this point brought out more forcefully than in the case of weatherproof and slow-burning wire. Engineers pointed out that electric utilities are extremely cost conscious in buying wire. The insulation and covering on this type of wire, moreover, is not required to withstand the demands made against the insulation of other wires. There is no problem of protecting buildings or machinery from fire or other damage or breakdowns. The jacket on weatherproof wire serves primarily to protect the lineman or other person who comes in contact with the wire. Insulation of such wire is required by most local governments in this country.

The extreme cost consciousness of buyers of weatherproof wire has an important bearing on cotton's present and future position in this market. One firm reported that the cost of copper was encouraging the use of aluminum conductors with these implications for cotton:

> "There is some trend in this field (weatherproof wire) toward using aluminum rather than copper conductors because of cost and light weight. Aluminum has about two-thirds of the conductivity of copper but only one-third of the weight. Because of this poorer conductivity, aluminum conductors have to be larger than copper ones. This means we can use them only where space is no problem, but to conserve space, we use a thinner insulation over a larger conductor--this eliminates cotton! . . . also, aluminum is soft whereas copper is hard, and there is consequent danger of cutting a soft conductor if you have to cut into a braided (cotton) covering. There is no such danger if the covering is polyethylene."

Automotive and Aircraft Wire and Cable

Scope and Importance

Included in this category are all types of automobile and aircraft wire and cable, including ignition harness sets and cable sets. In general, these types of wire must carry discontinuous currents of very high voltage and with such steep wave fronts as to approximate high-frequency surges. This condition forces the insulation to operate at all times under the transient conditions that are the exception for other types of conductors.

Aside from this common operating requirement, however, aircraft wires differ from automotive wires in most other respects: they must operate under a much wider range of temperature conditions and atmospheric pressures, and they must meet tighter weight and diameter limitations. These differences between automotive and aircraft wire requirements are reflected in the differing insulations and coverings used in these two applications.

The 1947 Census of Manufacturers' Sales reported that almost 10 percent of the total sales of insulated electrical wire in that year were automotive and aircraft wires and cables. The value of these shipments was $83,724,000. However, two factors have since increased the relative importance of these classifications of wire beyond 10 percent. One factor is the marked increase in the production of both automotive vehicles and aircraft since 1947. The other is the growing complexity of military jet aircraft (which require electrical ignition for starting).

Trends in Use of Fibers

Plastics (almost entirely vinyl compound) account for more than half of all the material used in covering and insulating automotive and aircraft wire. Cotton (mostly in yarn form) and rubber (mostly synthetic) divide the remainder of this field about equally. Fibrous glass is being used by one of the major manufacturers as an inner covering because of its heat resistance in jet engine installations.

Of the five major manufacturers producing automotive and aircraft wire, three reported that they are using cotton in the outer coverings only. However, two of these companies are also producing wires with outer coverings of plastics--including polyvinyl chloride, polyethylene, nylon, and neoprene. The two major producers who do not use any cotton in these products have both discontinued its use within the past five years. They are both engaged in the production of aircraft wire, to the exclusion of automotive wire, and reported:

> "Wire produced was made for the Government to Federal specifications. Specifications were changed to call for vinyl insulation and no covering. Vinyl is superior to

rubber insulation and cotton braid in resistance to oil, abrasion and moisture. No price differential in new wire as compared to cotton covered."

"Because of higher test requirements for wire in aircraft, particularly military. Wire has to be more resistant to deterioration from extreme low temperature, moisture, and must bend in cold weather (Arctic Air Bases). Wire, also, must not wick."

Opinion was general that cotton has largely disappeared from the aircraft wire coverings market. Until research can overcome these problems, cotton will not be able to equal plastics (or with fibrous glass) in the important respects of resistance to temperature extremes, resistance to moisture, and reduced bulk.

The importance of cotton in the automotive wire and cable classification, as distinct from aircraft wire, is still great at present. A consensus as to its outlook for the immediate future has been expressed as:

> "Cotton is 'holding its own.' The auto industry has been slow to replace cotton, although neoprene is basically far superior from an engineering standpoint, since cotton braid has to be filled with asphaltic compound and varnished--these are slow and therefore expensive manufacturing processes. Neoprene is fast to apply and is resistant to oil--important in engines. It is also resistant to high temperature. . . . Automobile wiring is still largely cotton braided. . . .In autos, this wire is not exposed to the customer usually, so there is less incentive to change than in the case of appliance wire, for example, although plastics are far more resistant to oils and acids. . . ."

Magnet Wire

Scope and Importance

The wire used to form the coils or windings in electric motors, generators, transformers, and similar devices is known as magnet wire. It consists of a round, square, or rectangular copper conductor which is covered by one or more thin layers of protective materials. Much of this wire is produced in accordance with specifications established by the National Electrical Manufacturers' Association and American Standards Association. Some users, however, set up their own requirements to which the wire manufacturers conform in filling special orders.

According to the 1947 Census of Manufacturers' Sales, shipments of magnet wire were valued at just under $135,000,000 in that year. This was approximately 15 percent of the value of all insulated electrical wire sold. Most of this wire, however, was insulated only with enamel. Fibers were used in the manufacture of only about $45,000,000 worth of it.

Trends in Use of Fibers

The requirements of the electrical apparatus in which magnet wire is incorporated are such that the materials used in the insulation must both insulate and cover the wire. Space is too limited to permit, in most cases, the use of separate insulating and covering materials. Even where cotton is applied over a film of enamel or vinyl compound it is expected usually that the dielectric properties of the insulation will be enhanced. It is unnecessary, therefore, in analyzing the magnet wire market to distinguish between trends in use of materials as coverings and as insulation.

Seven of the ten large wire manufacturers produce magnet wire. The most widely used natural material was cotton. Six companies were using it; while four used paper. One company also employs some silk in small windings where attractive appearance was desired. Some experimentation with asbestos compounds was also reported.

Among the other materials, fibrous glass was mentioned most frequently. Six companies were using it, while four employed a vinyl resin compound.

Trends in the use of materials to insulate this wire clearly favor the synthetics. Both vinyl compound and fibrous glass were expected to grow in importance. Paper seemed to have the best chance of the natural materials to retain its present standing. To a certain extent paper has been displacing cotton. One engineer commented:

> "Cotton is declining in importance. The cotton is applied over either an enamel or paper insulation. Over paper, cotton serves to hold the paper in place as well as resisting abrasion. A fine cotton is required for this purpose--a type which was not available during World War II. In the experimentation to find a replacement a more flexible paper was found. This very thin manila stock is now used with more overlap and no cotton outer protection is needed."

Five of the six manufacturers who were using cotton in this type wire stated that cotton had lost stature in their business in recent years. Representatives of the other company felt that cotton had held its own in their firm in the last five years. They reported however, that over a longer period, say the last 10 years, their consumption of this material had also dropped.

There was general agreement in the magnet wire industry that they planned to use less cotton in the future. Two engineers, however, pointed out that the demand for magnet wire had increased rapidly in recent years. While less and less cotton is being used in relation to total output, their purchases of cotton for this use may continue somewhere near present levels for a year or two. Shortages of other materials and increasing total demand could bring this about.

As shown in table 1, silk and asbestos are of minor importance in the manufacture of this type of wire. No important changes in the use of either material was anticipated.

Reason for Changing Patterns of Use

Both the price and properties of fine cotton yarn in relation to the attributes of synthetics and paper have an important bearing on cotton's declining position in the magnet wire market. The representative of one company stated:

> "Synthetic enamels, vinyl compound, and now, fibrous glass have come along to displace cotton in a type of wire in which it was formerly used in very large quantities. The superior dielectric strength of the vinyls and enamels and the high heat resistance of glass have encouraged their substitution for cotton."

Another engineer emphasized price as well as properties of materials as follows:

> "The trend is toward the production of magnet wire which will withstand higher temperatures and operate in smaller spaces. Glass is superior to cotton on both of these counts. Glass has also displaced asbestos because of its superior resistance to heat and utilization of less space.
>
> "Fine cotton, moreover, has to be used on magnet wire for space reasons. This type of cotton is expensive and the trend in price has been upward. Fine glass, on the other hand, has been declining in price."

Still another engineer, while emphasizing the problem of space, elaborated on the cost differential:

> "A very fine cotton is needed for magnet wire. This type of yarn is very expensive, perhaps $2 a pound. Cotton is being displaced not only because of its initial cost, however. The cost of manufacturing cotton-covered wire and the cost of winding coils is greater than with many other materials. Wire diameter is a factor too.

A wire insulated with a vinyl varnish is of smaller diameter than a cotton insulated wire. Smaller diameter wire allows the production of apparatus of smaller size than formerly with consequent savings on steel.

> "Coils, moreover, can be wound more rapidly when the synthetic varnish is used. More tension can be placed on vinyl while winding than on cotton. (Cotton breaks.) More tension means a faster and tighter (less space) wind."

Also, paper, was believed to be superior to cotton in many types of magnet wire. One engineer gave the following specific example of the substitution of paper for cotton.

> "A popular transformer wire used to have a 2 paper and 1 cotton wrap specification. Now a 4 paper cover is used. This produces a wire of smaller diameter than the former type as well as a wire having superior dielectric properties. Smaller diameter wire allows the transformer manufacturer to produce a smaller transformer using less steel for a given electrical capacity."

Cotton faces a disadvantage in competing with vinyl compounds and fibrous glass in most types of magnet wire. Where cotton is used, the resulting wire is of greater diameter than when other materials are employed. And cotton is unable to withstand the high temperatures--100 - 130 degrees centigrade--in which fibrous glass can operate successfully. The existing trend toward smaller space and higher temperatures works strongly against cotton.

Then, too, the fine, soft-spun, long-fiber, Combed Peeler cotton yarn required for this type of wire is relatively expensive. This initial cost is not offset by economies in production. Indeed it appears that it is cheaper to produce a vinyl wire and cheaper to wind it in coils. For these reasons an engineer of one company remarked:

> "We are producing cotton wire now largely for repair of old wire which is outstanding. New installations are nearly always made with some material other than cotton."

In two other firms, however, it was felt that cotton would still play an important role in the insulation of some types of magnet wire. Cotton's ability to withstand great abuse in the winding process is in its favor. And in some magnet wires the bulkier wall of cotton, in comparison to other materials is an advantage.

For example, in winding coils with heavy size conductors, the thickness of the cotton is of small moment compared to the total diameter. Such wires are frequently rectangular or square and may be hammered into place. Cotton will withstand the tension and abuse of such installation where most other materials, including the newer ones, do not.

It seems likely then that cotton will continue to be used to insulate some kinds of magnet wire. It has lost much of this market, however, and will undoubtedly lose more in the next five years. Paper, on the other hand, will probably maintain its present position.

IMPROVING MATERIALS USED FOR INSULATING AND COVERING ELECTRIC WIRE AND CABLE

The engineers and production executives of the 10 large wire manufacturing firms interviewed in detail in the course of this survey were asked to submit any suggestions they might have for improvements in the various materials used for insulating and covering electric wire and cable. No limit, of course, was placed on the type of improvement they might suggest, and some of the suggestions are quite ambitious. The comments of these informed individuals, however, do highlight the problems existing on each material, and may suggest avenues of research which may prove productive. Considering each of the several materials discussed individually the comments made are discussed below:

Cotton Yarn

1. Make cotton yarn flame resistant--operating temperatures on many applications are increasing and inflammability is important in building wire.

2. Reduce water absorption to cut down effects of rot and mildew. This presumably will require a new saturant, or a resistant characteristic which will not eliminate present saturant absorption characteristics.

Other improvements requested--by one authority only in each case--were an improved wax treatment and an improved resistance to bacteria and sunlight.

In the processing area there were also two items mentioned quite frequently:

1. A need for less linting. The factory housekeeping problem resulting from this characteristic is presumably minor, but an improvement here would be looked upon with favor.

2. An increase in tensile strength relative to width. This request was made most frequently in relation to breakage in braiding, but also would improve cotton's acceptability where diameters are crucial from an application standpoint.

Other suggestions for processing improvements mentioned were the elimination of the tendency of the yarn to knot when slack, and for the development of characteristics which will permit faster processing than present braiding methods.

On the subject of price the manufacturers were uniformly agreed that cotton's price was a definite handicap. They agreed that the difference in price between cotton yarn and glass yarn was more than sufficient to encourage the use of glass wherever possible.

There were no complaints on variation of quality in cotton yarns, or on its availability.

Cotton Tapes

There was considerably less agreement among the manufacturers on desirable improvements which might be made in cotton tape. More of the producers use the material in this form and seven of them had one suggestion or more. However, no one item was mentioned by more than two. The suggestions made are listed below:

1. Reduce tape thickness.

2. Improve heat resistance.

3. Improve dielectric properties.

4. Reduce moisture absorption.

5. Improve sizing so that it does not make varnish impregnation spotty.[4]

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[4] Mentioned by one firm. It reports that present sizing leaves "pimples" which are not properly impregnated. This leads to faster deterioration. The suggestion carried the condition, however, that the flexibility of the tape must not be sacrificed or impaired.

Only one suggestion was made for a change which would aid processing--that the tape be selvaged to reduce raveling.

Cotton in tape form apparently can compete favorably with fibrous glass tape in price, but it still is at a price disadvantage compared to rubber and paper.

There have been no recent supply problems on cotton tape, and only one firm commented on a lack of uniform quality. This firm's statement was as follows:

> "The thickness of rubber-faced and varnished cambric tapes varies too much. The tensile strength varies. Color coding is not always true: especially on rubber-faced tape--red is a washed out pink, white is a dirty gray."

Other Natural Materials

Only one engineer made suggestions on natural materials other than cotton, commenting that an improvement was needed in the tensile strength of asbestos tape and that its dielectric properties were poor. The same engineer also stated that rubber-faced linen tape was too thick for some of the applications for which it is suitable.

Synthetic Materials

While isolated comments were made on vinyl-faced type and rayon yarn, the synthetic material most frequently mentioned as needing improvement was fibrous glass--both as a yarn and as a tape.

As a yarn, glass is admittedly attractive on a price basis but it presents some real problems in processing. Some of them are the following:

1. It is too abrasive. The strands injure workers hands and it abraids itself. In addition the abrasiveness is hard on braiding and knitting machines.

2. It makes workers "itch". One engineer characterized this as an allergic reaction; another stated that improvement has been evident recently but added that the problem has not been solved.

3. The yarn does not satisfactorily hold a saturant.

4. The yarn breaks when drawn through a conduit.

5. The yarn must be lubricated when starch is applied.

6. It lacks flexibility.

As a tape, fibrous glass costs substantially more than varnished cambric and presents the following problems:

1. It has a tendency to crack when wrapped on wire of small diameter.

2. It may break when bent sharply.

3. Like the yarn it needs to be made more absorbent to retain saturants.

The most recurrent comment on this product, however, was on its high price.

There were no complaints made of nylon yarn performance, but almost all of the contributors commented on its high price and stated that it was a product on which the price was sufficiently different to discourage its use in many situations.

The comment made on vinyl-faced tape suggested a need for improved quality control to insure a more uniform thickness, and two engineers felt that the tensile strength of rayon should be increased to cut down breakage in the braiding process. One of these two also felt that the absorption characteristic of rayon could be improved.

PURCHASING PRACTICES APPLYING TO INSULATING MATERIALS

Cotton Yarn [5]

All of the 10 large wire manufacturers use and purchase cotton yarn, and without exception they reported that purchase was made by specification. The specifications used by all concerns are those developed by the American Society of Testing Materials. Industry engineers have participated in the preparation of the specifications and apparently they are fully acceptable to these large manufacturers.

Only 1 of the 10 firms does not test cotton yarn. The others variously reported use of American Society of Testing Materials and Insulated Power Cable Engineers Association tests which include the following checks:

1. Tensile strength
2. Weight
3. Amount of twist
4. Breaking strength
5. Type of package
6. Diameter

Cotton Cambric

A similar situation prevails on cotton cambric. The nine large manufacturers purchasing this material buy exclusively on a specification basis, use American Society of Testing Materials specifications, and all but one tests the material. Some of the same checks are made but also checked are dielectric properties and the power factor.

Other Yarns and Fabrics

The situation on other yarns and fabrics is shown in the tabulation below. Again specification buying, the use of standard industry guides, and testing is widely prevalent. The instances of grade purchase shown are all reported by one firm.

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[5] All 10 firms report no current purchases of raw cotton, cotton slivers or cotton rovings.

Purchase and testing practices on yarns and fabrics other than cotton

Material	Number of firms using	Number purchasing by specification	Number purchasing by grade	Number testing
Acetate yarn-------------	5	5	-	4
Acetate tape-------------	3	3	-	3
Asbestos yarn------------	5	5	-	5
Asbestos tape------------	3	3	-	3
Fibrous glass yarn-------	8	7	1	5
Fibrous glass tape-------	5	4	1	3
Jute---------------------	8	7	1	4
Linen tape---------------	1	1	-	1
Nylon yarn---------------	4	4	-	3
Rayon yarn---------------	6	5	1	4
Sisal--------------------	2	2	-	2

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